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(54) Title: A SIMULATOR FOR TESTING A COLLISION AVOIDANCE RADAR SYSTEM
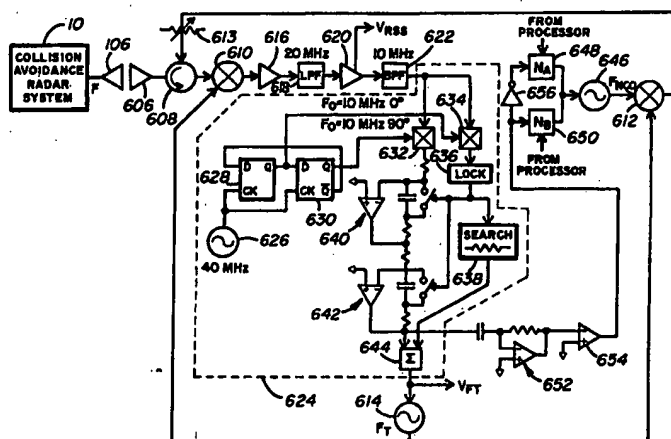
(57) Abstract

A simulator for testing the performance accuracy or calibrating a collision avoidance radar system. The simulator includes circuitry for receiving a signal from the collision avoidance radar system and for generating a signal tracking the frequency of the radar system. Circuitry is further included in the simulator utilizing the tracking signal to generate a signal offset in frequency from the collision avoidance radar system output signal and to transmit the offset signal to the collision avoidance radar. The offset is controlled so that the collision avoidance radar should indicate an object is located a distance (D) away. Circuitry is further included in the simulator so that the offset has a first value when the radar system output is increasing in frequency and a second value when the radar system output is decreasing in frequency. The first and second offset values are controlled so that the radar system should indicate an object is moving at a rate (dD/dt) upon receiving the offset signal. The simulator further indicates the frequency range and amplitude of the radar system output as determined from the tracking signal.

A SIMULATOR FOR TESTING A
COLLISION AVOIDANCE RADAR SYSTEM

5   BACKGROUND OF THE INVENTION
1.   Field of the Invention
      The present invention relates to a device for
testing the performance accuracy or calibrating a
collision avoidance radar system.
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2.   Description of the Related Art
      Fig. 1 shows components of a collision avoidance
radar system 10 along with a 1^2 meter metal plate 108
typically   utilized   as   a   simulator   to   test   the
15   performance accuracy of the radar system.
      The collision avoidance radar system 10 shown in
Fig. 1 is typically installed in an automobile with the
antenna   106   in   the   front   or   grill   area   of   the
automobile.   The   system   operates   by   transmitting   a
20   signal   from   the   antenna   106   and   determining   from   a
signal received back the distance (D) the antenna 106 is
from simulator 108 or other reflecting object, such as
another automobile.   From the received signal, the radar
system 10 can also determine the rate (dD/dt) the object
25   or   other   vehicle   is   moving.   By   processing   the   received
signal,   an   alarm   or   other   device   can   be   activated   to
enable the vehicle operator to avoid a collision with
the object or vehicle.
      The system shown in Fig. 1 includes a oscillator
30   .100 configured to sweep over a range of frequencies.
The output of oscillator 100 is provided to a splitter
102.   A first output of splitter 102 is provided as a
local   oscillator   signal   (F_{LO})   to   the   first   input   of   a
mixer 110.   A second output of the splitter 102 is
35   provided to isolator 104.   The isolator 104 provides the
signal from the splitter 102 to the input of the antenna
106 to be transmitted, and provides the signal received

from the antenna 106 as an RF signal (F_{RF}) to a second input of mixer 110.

The oscillator 100 typically sweeps through a range of frequencies having a minimum of 76 GHz and a maximum
5   of 77 GHz. The 76-77 GHz range is assigned by the Federal Communications Commission (FCC) for collision avoidance radar systems. The oscillator 100 typically sweeps through a 250 MHz range of frequencies within the 76-77 GHz limits in a 1.2 msec time period as
10   illustrated in Fig. 2. In Fig. 2, the sweep range is centered at 76.5 GHz, but the 250 MHz range may also be found centered closer to one of the 76 GHz or 77 GHz limits.

The signal provided from the oscillator 100 is
15   provided through the isolator 104 and antenna 106 as a transmitted signal which is illustrated in Fig. 3. A reflected signal is then received by the antenna 106 and provided by the isolator 104 as the F_{RF} signal, also as illustrated in Fig. 3. The received signal is shown in
20   Fig. 3 shifted in frequency from the transmitted signal and will be shifted in frequency dependent on the distance D, shown in Fig. 1. The distance D is a distance which a reflecting object such as the 1^2 meter standard 108 is located from the antenna 104. If the
25   distance D is zero, no frequency shift will occur between the transmitted and received signals.

Fig. 3 also shows an intermediate frequency signal F_{IF} which is the difference in the transmitted signal F_{LO} and the received signal F_{RF} provided at the inputs of
30   mixer 110. Because the mixer 110 cannot distinguish between positive and negative, the actual signal provided from mixer 100 F_{IF} is a positive frequency signal changing with time as illustrated in Fig. 4. The frequency of the signal F_{IF} output from mixer 110 is
35   converted to a corresponding voltage by a discriminator, or frequency to voltage converter 112. Since transitions such as 120 occur at regular 1.2 msec

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intervals, as shown in Fig. 4, the transitions 120 can be filtered out by the discriminator 112. The voltage output from discriminator 112 can then be processed to determine the distance D.

5   An equation for determining the distance D based upon the frequency value of F_{IF} output from mixer 110 can be derived as shown below with knowledge of the 250 MHz sweep range and 1.2 ms time period provided by oscillator 100. First, time (t) in seconds is related

10   to the distance D in meters and the speed of light (c) as follows:

$$t = D/c \tag{1}$$

15   where c = 299.8 X 10^6 meters/sec. Further, the frequency difference in the transmitted and received signals F_{IF} is related to time t as follows:

$$F_{IF} = t\Delta t/\Delta f \tag{2}$$

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where Δf is the frequency sweep range provided by oscillator 100, and Δt is the time period over which the frequency range is swept by oscillator 100. Combining equations (1) and (2), F_{IF} is obtained in terms of D as

25   follows:

$$F_{IF} = D\Delta f/c\Delta t \tag{3}$$

30   D in terms of F_{IF} is then:

$$D = F_{IF}c\Delta t/\Delta f \tag{4}$$

With Δf = 250 MHz and Δt = 1.2 msec, a frequency

35   difference F_{IF} of 695 Hz will be provided for a distance D of 1 meter as seen from equation (4).

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The rate an object is moving toward or away from the antenna 106, or the change in D with respect to time (dD/dt) can also be determined by the circuitry of Fig. 1. With the object, such as simulator 108, moving

5   farther away from the antenna 106, the received signal will increase in frequency relative to the transmitted signal as shown in Fig. 5A. With an object moving away, frequency F_{IF} provided from mixer 110 during a period Δt when the transmitted signal is increasing in frequency

10   will be smaller than during a period Δt when the transmitted signal is decreasing in frequency, dependent on dD/dt, as illustrated in Fig. 5A. With an object moving closer to the antenna 106, the received signal will decrease in frequency relative to the transmitted

15   signal as shown in Fig. 5B. With an object moving closer, frequency F_{IF} provided from mixer 110 during a period when the transmitted signal is increasing in frequency will then be larger than during a period when the transmitted signal is decreasing in frequency,

20   dependent on dD/dt, as further illustrated in Fig. 5B. By measuring the difference in frequency between sweep periods, dD/dt can, thus, be determined.

To assure proper performance of the collision avoidance radar of Fig. 1, the device must be regularly

25   tested or calibrated. During calibration, assurances must be made that the oscillator 100 is operating inside the 76-77 GHz range specified by the FCC, even though the radar may be functioning properly outside that range. Further, the 250 MHz sweep range Δf and 1.2 msec

30   sweep period Δt must be verified to assure accurate distance calculations are being made using equation (4). A receiver is typically connected to the oscillator 100 during calibration to assure the oscillator is functioning properly.

35   Calibration is also performed using the simulator 108 to check that the radar indicates proper distances D accurately up to 100 meters. The simulator 108 is

also utilized to assure the radar system indicates proper change in distance measurements dD/dt as described above.

A disadvantage of utilizing the 1^2 meter metal plate standard for a simulator, however, is that a large area is required for performing simulation. Another disadvantage is the awkwardness in moving the plate a specified distance during a specified time to determine dD/dt.

SUMMARY OF THE INVENTION

The present invention enables testing a collision avoidance radar system while using significantly less space than a 1^2 meter metal plate standard requires. Further, dD/dt tests can be made without requiring the awkward movement of equipment as is required with a 1^2 meter plate simulator.

The present invention also enables testing the frequency sweep range Δf and time period Δ of a signal provided from oscillator 100 without requiring that additional test equipment be connected to the oscillator.

The present invention is a simulator including circuitry for receiving a signal from a collision avoidance radar system as shown in Fig. 1 and for generating a signal tracking the frequency of the radar system. The simulator of the present invention further includes circuitry which utilizes the generated tracking signal to generate a signal offset in frequency from the collision avoidance radar system output signal and to transmit the offset signal to the collision avoidance radar. The offset is controlled so that the collision avoidance radar should indicate an object is located a distance (D) away.

The present invention further includes circuitry controlling the offset to have a first value when the radar system output is increasing in frequency and a

second value when the radar system output is decreasing
in frequency so that the offset signal causes the output
of mixer 110 to appear as shown in Figs. 5A and 5B. The
first and second offset values are controlled so that
5   the radar system should indicate an object is moving at
a rate (dD/dt) upon receiving the offset signal.

The simulator further includes components to
indicate the frequency range and amplitude of the radar
system output as determined from the tracking signal
10   which it generates.

BRIEF DESCRIPTION OF THE DRAWINGS

Further details of the present invention are
explained with the help of the attached drawings in
15   which:

Fig. 1 shows components of a collision avoidance
radar system along with a simulator to test the
performance accuracy of the radar system;

Fig. 2 illustrates a 250 MHz range of frequencies
20   provided from an oscillator of Fig. 1 during a 1.2 ms
time period;

Fig. 3 shows transmitted and received signals from
the radar system of Fig. 1 along with a signal F_{IF} which
is the difference in the transmitted and received
25   signals;

Fig. 4 shows a signal provided from the mixer of
the radar system of Fig. 1;

Fig. 5A shows transmitted and received signals from
.the radar system of Fig. 1 when an object is moving
30   farther away from the radar system, along with a signal
F_{IF} provided from a mixer of the radar system;

Fig. 5B shows transmitted and received signals from
the radar system of Fig. 1 when an object is moving
closer to the radar system, along with a signal F_{IF}
35   provided from a mixer of the radar system;

Fig. 6 shows a simulator of the present invention utilized to test or calibrate a collision avoidance radar system;

Fig. 7 shows a typical configuration for a
5   numerically controlled oscillator (NCO); and

Fig. 8 illustrates a signal provided to the differentiator of Fig. 6 and the resulting output of the differentiator.

10   DETAILED DESCRIPTION

Fig. 6 shows a simulator of the present invention utilized to test or calibrate a collision avoidance radar system 10 as shown in Fig. 1. The simulator includes an antenna 106 which in operation is placed
15   immediately next to the antenna 606 of the collision avoidance radar system 10. The antenna 606 is connected to an isolator 608 which provides a received signal (F) received from the radar system 106 to a first input of mixer 610. The isolator 608 is also connected to the
20   output of a mixer 612 to provide a signal from mixer 612 as a transmitted signal through antenna 606 to the radar system 10. An attenuator 613 is connected between mixer 612 and isolator 608 so that a signal transmitted from the antenna 606 will simulate the signal strength of a
25   similar signal reflected from an object at a distance D.

A tracking signal F_T is provided to a second input of mixer 610 and mixer 612 by a voltage controlled oscillator (VCO) 614. The tracking signal F_T is controlled to track the received signal F with a
30   frequency offset by a reference signal Fo. The reference signal Fo in Fig. 6 is assumed to be 10 MHz, although other values may be chosen.

When the signal F_T is tracking the signal F with an offset Fo, the output of mixer 610 will be a signal
35   having the reference frequency Fo along with broadband noise. The output of the mixer 610 is provided through a preamplifier 616 to a low pass filter 618. The low

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pass filter 618 functions to limit broadband noise in a
signal applied to amplifier 620 so that the signal to
noise ratio for the amplifier 620 is within acceptable
limits. Here, the filter 618 is shown to be a 20 MHz
5   filter, assuming Fo=10 MHz. The amplifier 620 provides
a relative signal strength signal (V_{RSS}) test connection
enabling an amplitude of the signal F from the collision
avoidance radar system to be determined. The amplifier
620 further provides a square wave output with a fixed
10   amplitude to bandpass filter 622. The bandpass filter
622 provides a fixed amplitude sine wave output having
a bandpass range centered on the reference signal Fo,
here 10 MHz.

A phase detector 624 receives the output of
15   bandpass filter 622. The phase detector 624 compares
the signal from filter 622 with the reference signal Fo
and provides an output indicating any difference to the
voltage control input of VCO 614. The phase detector
624, which is preferred, has components illustrated in
20   Fig. 6 which are found in a Wiltron 360 Analyzer
manufactured by Wiltron Company, Morgan Hill, CA. The
phase detector 624 is a quadrature phase detector as
configured in the Wiltron 360 Analyzer because the
signal F_T could be F ± Fo, and the circuitry of the phase
25   detector 624 enables detection of a desired one of the
signals, preferably F+Fo, so that the tracking signal F_T
can be used to accurately measure the frequency of the
collision avoidance radar signal F. For example, with
F=76.5 GHz and Fo=10 MHz, with a phase detector which
30   cannot distinguish between $F-F_T$ or F_T-F when phase lock
is obtained, the signal F_T could be either 76.51 GHz or
76.49 GHz. The phase detector 624 configured as shown
would enable detection of only the 76.51 GHz signal.

To generate the reference signal Fo, the phase
35   detector 624 includes an oscillator 626 and two D-type
flip-flops 628 and 630. The oscillator 626 provides a
signal four times the reference signal frequency, here

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40 MHz, to the clock inputs of flip-flops 628 and 630.
The Q output of flip-flop 628 is connected to the D
input of flip-flop 630. The $\overline{Q}$ output of flip-flop 630
is connected to the D input of flip-flop 628. As

5   connected, the Q outputs of the flip-flops 628 and 630
each provide the 10 MHz signal Fo, the Q output of flip-
flop 628 being 90 degrees out of phase with the Q output
of flip-flop 630.

       The Q output of flip-flop 628 is provided to a

10   first input of multiplier 634 and the Q output of flip-
flop 630 is provided to a first input of multiplier 632.
Second inputs of multipliers 632 and 634 are provided
from filter 622. The output of multiplier 634 is
provided to a lock signal generator 636.

15   The lock signal generator 636 provides an unlock
signal when the signal provided from multiplier 634 from
bandpass filter 622 is absent or is $F-F_T$, and a lock
signal when the signal provided to multiplier 634 by
bandpass filter 622 is F_T-F. The lock signal generator

20   output is provided to a search signal generator 638, as
well as to integrators 640 and 642 connected in series
to the output of multiplier 632.

       The search signal generator 638 provides an output
through summer 644 to the input of oscillator 614. The

25   search signal generator 638 provides a continuously
sweeping signal to sweep a frequency at the VCO 614
output through the range of possible frequencies for F
when the lock signal generator 636 indicates an unlocked
condition. The search signal generator 638 has its

30   output signal disabled when the lock signal generator
indicates a locked condition when the signal F_T is
tracking the signal F with an offset of Fo.

       The series integrators 640 and 642 likewise provide
a signal through summer 644 to the input of VCO 614.

35   The integrators 640 and 642 each include a switch
connected in parallel with a capacitor. The switch is
controlled by the output of the lock signal generator to

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be closed in an unlocked condition and opened in a locked condition. In an unlocked condition integrators 640 and 642 are disabled and the output of multiplier 632 is provided to summer 644 with a low gain and a finite phase error. However, in a locked condition, integrators 640 and 642 are enabled and provide a signal from multiplier 632 with a zero phase error and high gain through summer 644 to control the VCO 614 input so that the signal F_T tracks the signal F with an offset Fo.

In operation, the lock signal generator 636 will initially be in an unlocked state. The search signal generator 638 will then provide a sweeping voltage to summer 644 causing the signal F_T from VCO 614 to sweep through frequencies of approximately 76-77 GHz. Further, the lock signal generator will disable integrators 640 and 642 so the multiplier 632 will provide a low gain signal path to VCO 614 which will momentarily phase lock VCO 614 if the search signal generator 638 causes VCO 614 to sweep through F±Fo. If the signal F_T is not equal to F±Fo, the DC signal provided from multiplier 634 to lock signal generator 636 will be 0 volts. If the signal F_T=F-Fo, the DC signal provided from multiplier 634 to lock signal generator 636 will be an average positive voltage value. If the signal F_T=F+Fo, the DC signal provided from multiplier 634 to lock signal generator 636 will be an average negative voltage value. The lock signal generator 636 is preferably set to indicate lock only when the output of multiplier 634 indicates F_T=F+Fo. If F_T is not equal to F±Fo, the lock signal generator 636 will continue providing a signal indicating an unlocked condition and search signal generator 638 will continue sweeping a voltage at its output. If F_T=F+Fo, the lock signal generator 636 will disable search signal generator 638, and enable integrators 640 and 642 enabling the signal F_T to be phase locked with the signal F plus an offset

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Fo. Note that although the lock signal generator 636 indicates lock when $F_T = F + Fo$, it may be alternatively set to indicate lock when $F_T = F - Fo$ by accepting the average positive voltage value.

To provide an indication of the frequency of F, the voltage control input to VCO 614 is provided as a test connection to provide the signal V_{FT}. The signal V_{FT} enables determination of the frequency of F when phase lock is obtained without requiring a connection to the oscillator 100 of the collision avoidance radar system 10 shown in Fig. 1 as in previous test configurations.

A second input of mixer 612 is connected to the output of a numerically controlled oscillator (NCO) 646. A typical 32 bit NCO is the Analog Devices AD9850. A configuration for a 4 bit NCO 646 is shown in Fig. 7, although a 32 bit NCO is preferably utilized. The NCO of Fig. 7 includes a series of D flip-flops 700 with Q outputs connected to a first set of inputs A_{0-3} of an adder 702. Outputs Σ_{0-3} of the adder 702 are then fed back to the D inputs of the flip-flops 700. A second set of inputs B_{0-3} to the adder are provided as an input (INPUT) to the NCO. The Q outputs of flip-flops 700 are further provided through a sine output read only memory (SINE ROM) 704 and D/A converter 706 to provide the output of the NCO $(F_{NCO.})$

In operation, a count provided by adder 702 will proceed with the clock (CK) provided to flip-flops 700 and proceed in increments depending on the B_{0-3} input to the adder 702. For instance, if the B_{0-3} input is 0001, the count will proceed by binary 1's, or if the B_{0-3} input is 0010, the count will proceed by binary 2's. The SINE ROM 704 output will then increase in value until overflow of the adder 702 and then reset creating a signal at the output (SINE OUTPUT) of the D/A converter 706 having a frequency controlled by the B_{0-3} input. For the four bit NCO of Fig. 7, the output of the NCO $F_{NCO} = $ SINE OUTPUT $= $ (INPUT)(CK)$/2^4$.

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An input (INPUT) to the NCO 646 in Fig. 6 is
provided from registers 648 and 650. The values N_A and
N_B stored in registers 648 and 650 and an appropriate CK
provided to the NCO 646 enables the NCO 646 to provide

5   a signal F_{NCO} having the frequency of the reference
signal Fo offset by an amount ΔF as controlled by
registers 648 and 650.

The output of mixer 612 will be $F_T \pm F_{NCO}$. The
signal FT + F_{NCO} will be above the range of frequencies

10   accepted by the collision avoidance radar 10 and will be
filtered out as long as Fo is selected as a high enough
value, such as the 10 MHz signal suggested. With F_T
being F+Fo, and F_{NCO} being Fo-ΔF, the output of mixer 612
provided to the collision avoidance radar system will

15   then be $F_T - F_{NCO} = (F+Fo)-(Fo-\Delta F) = F+\Delta F$. The values
stored in registers 648 and 650 are provided by a
processor and controlled so that offset ΔF will cause
the collision avoidance radar system 10 to indicate an
object is located a chosen distance D away.

20   Two separate registers 648 and 650 are utilized to
enable the offset ΔF to be controlled to cause the
collision avoidance radar system 10 to indicate an
object is moving at a rate dD/dt. To control the
registers 648 and 650 so that ΔF can indicate a rate

25   dD/dt, the circuit of Fig. 6 includes a differentiator
652, comparator 654 and inverter 656.

The differentiator 652 has an input connected to
integrator 642. With the integrator 642 providing a
signal 800 as shown in Fig. 8 when phase lock occurs,

30   the output of the differentiator 652 will be the signal
802. Because the signal 800 increases and decreases
voltage in correspondence with any increase or decrease
in the frequency of F, the state of signal 802 will
indicate whether F is increasing or decreasing in

35   frequency. To provide a voltage swing to adequately
drive subsequent circuitry, the output of differentiator
652 is provided through a comparator 654. The output of

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comparator 654 will, thus, transition between ground or a logic 0 and a logic 1 depending on whether the signal F is increasing or decreasing in frequency.

5   The output of comparator 654 is provided to an enable input of register 650. The output of comparator 654 is further provided through an inverter 656 to an enable input of register 648. As connected, when F is increasing in frequency the output of one of registers 648 and 650 will be enabled, and when F is decreasing in

10   frequency the output of the other one of registers 648 and 650 will be enabled. With a processor providing different values N_A and N_B to registers 648 and 650, the signal transmitted from antenna 606 will make the output of the mixer 110 in the collision avoidance radar system

15   10 of Fig. 1 to appear as shown in Fig. 5. The values N_A and N_B stored in registers 648 and 650 are controlled so that the offset ΔF will cause the collision avoidance radar system to indicate an object is moving at a chosen rate (dD/dt).

20   Although the invention has been described above with particularity, this was merely to teach one of ordinary skill in the art how to make and use the invention. Many modifications will fall within the scope of the invention, as that scope is defined by the claims which

25   follow.

What Is Claimed Is:

1.   A method for testing a collision avoidance radar
system comprising:

5
        receiving a signal from the collision avoidance
radar system;

        generating a signal offset in frequency from the
signal received from the collision avoidance radar
system, the offset in frequency being controlled so that
the collision avoidance radar system should indicate an

10   object is located a distance (D) away upon receiving the
offset signal; and

        transmitting the offset signal to the collision
avoidance radar system.

15   2.   The method of Claim 1 wherein the step of generating
a signal offset in frequency comprises:

        generating a first portion of the offset signal
having a first difference in frequency from the signal
received from the collision avoidance radar system when

20   the signal from the collision avoidance radar system is
increasing in frequency; and

        generating a second portion of the offset signal
having a second difference in frequency from the signal
received from the collision avoidance radar system when

25   the signal from the collision avoidance radar system is
decreasing in frequency, the first difference in
frequency and the second difference in frequency being
controlled so that the collision avoidance radar system
should indicate an object is moving at a rate (dD/dt)

30   upon receiving the offset signal.

3.   The method of Claim 1 further comprising the step
of:

        indicating the frequency range of the signal from

35   the collision avoidance radar system as determined from
the offset signal.

4.   A simulator for testing a collision avoidance radar
system, the simulator comprising:
        an antenna (606) for providing a received signal
from the collision avoidance radar system and providing
5   a transmitted signal to the collision avoidance radar
system;
        a first mixer (610) having a first input, a second
input and an output;
        a second mixer (612) having a first input, a second
10   input and an output;
        an isolator (608) connected to the antenna for
providing the received signal from the antenna to the
first input of the first mixer and for providing the
output of the second mixer as the transmitted signal to
15   the antenna;
        a voltage controlled oscillator (VCO) (614) having
an output connected to the second input of the first
mixer and the second input of the second mixer, and
having a voltage control input;
20   a phase detector (624) having an input coupled to
the output of the first mixer, the phase detector
comparing a signal from the output of the first mixer
with a reference signal, the phase detector having an
output providing a signal to the voltage control input
25   of the VCO to enable the VCO output to provide a signal
having a frequency equal to the signal provided from the
collision avoidance radar system offset by the reference
signal frequency; and
        a numerically controlled oscillator (NCO) (646)
30   having an output connected to a first input of the
second mixer and an input, the NCO providing a signal at
its output equal to the reference signal frequency
offset by a amount as controlled by a numerical value
provided at the input of the NCO so that the collision
35   avoidance radar system should indicate an object is
located a distance (D) away upon receiving the
transmitted signal.

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5.   The simulator of Claim 4 further comprising:

a differentiator (652) having an input connected to
the phase detector and an output; and

a storage means (648,650,654,656) receiving the
5   differentiator output and providing a first numerical
value to the input of the NCO when the output state of
the differentiator indicates the VCO output should
increase frequency and providing a second numerical
value to the input of the NCO when the differentiator
10   output state indicates the VCO output should decrease
frequency, so that the collision avoidance radar system
should indicate an object is moving at a rate (dD/dt)
upon receiving the transmitted signal.

15   6.   The simulator of Claim 5 wherein the storage means
comprises:

a comparator (654) having a first input connected
to the output of the differentiator, a second input
connected to a voltage reference and an output;

20   an inverter (656) having an input connected to the
output of the comparator and an output;

first register (648) for storing a value, the first
register having an output connected to the input of the
NCO and having an enable input connected to the output
25   of the inverter; and

a second register (650) for storing a value, the
second register having an output connected to the input
of the NCO and having an enable input connected to the
input of the inverter.

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7.   The simulator of Claim 4 further comprising:
      a test connection (V_{FT}) coupled to the output of the
phase detector, the test connection indicating the
frequency range of the received signal from the
5   collision avoidance radar system as determined from a
signal at the output of the phase detector.

8.   The simulator of Claim 4 wherein the phase detector
is a quadrature phase detector comprising:
10   a first multiplier (634) having a first input
connected to the output of the first mixer, a second
input and an output;
          a second multiplier (632) having a first input
connected to the output of the first mixer, a second
15   input and an output;
          a reference signal generator (626,628,630) for
providing the reference signal to the second input of
the first multiplier and the second input of the second
multiplier, the reference signal provided to the first
20   multiplier being 90 degrees out of phase from the
reference signal as provided to the second multiplier;
          a lock signal generator (636) coupled to the output
of the first multiplier, the lock signal generator
providing a first signal when the first multiplier
25   output provides substantially a DC signal of a first
voltage value, and a second signal when the first
multiplier output indicates the output provides
substantially a DC signal of a second voltage value;
          a search signal generator (638) having an input
30   connected to the lock signal generator output and an
output coupled through a summer to the VCO input, the
search signal generator when receiving the first signal
from the lock signal generator providing a varying
voltage to the VCO input to sweep a frequency at the VCO
35   output through the range of frequencies which can be
provided by the signal from the collision avoidance
radar system, the search signal generator when receiving

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the second signal from the lock signal generator
disabling its output; and

5   at least one integrator (640,642) including a
switch connected in parallel with a capacitor for
coupling the output of the second multiplier through the
summer to the input of the VCO, the switch being
connected to the lock signal generator so that the
switch is controlled to close when the lock signal
generator provides the first signal and open when the
10   lock signal generator provides the second signal.

9.   The simulator of Claim 8 wherein the first voltage
value from the first multiplier is zero or a positive
value and the second voltage value from the first
15   multiplier is a negative value.

10.   A simulator for testing a collision avoidance radar
system, the simulator comprising:
        an antenna (606) for providing a received signal
20   from the collision avoidance radar system and providing
a transmitted signal to the collision avoidance radar
system;
        a first mixer (610) having a first input, a second
input and an output;
25   a second mixer (612) having a first input, a second
input and an output;
        an isolator (608) connected to the antenna for
providing the received signal from the antenna to the
first input of the first mixer and for providing the
30   output of the second mixer as the transmitted signal to
the antenna;
        a voltage controlled oscillator (VCO) (614) having
an output connected to the second input of the first
mixer and the second input of the second mixer, and
35   having a voltage control input;
        a numerically controlled oscillator (NCO) (646)
having an output connected to a first input of the

second mixer and an input, the NCO providing a signal at its output equal to the reference signal frequency offset by a amount as controlled by a numerical value provided at the input of the NCO;

5   a quadrature phase detector comprising:

a first multiplier (634) having a first input connected to the output of the first mixer, a second input and an output;

a second multiplier (632) having a first input 10   connected to the output of the first mixer, a second input and an output;

a reference signal generator (626,628,630) for providing the reference signal to the second input of the first multiplier and the second input of the second 15   multiplier, the reference signal provided to the first multiplier being 90 degrees out of phase from the reference signal as provided to the second multiplier;

a lock signal generator (636) coupled to the output of the first multiplier, the lock signal 20   generator providing a first signal when the first multiplier output is absent or is a positive DC voltage value, and a second signal when the first multiplier output is a negative DC voltage value;

a search signal generator (638) having an 25   input connected to the lock signal generator output and an output coupled to the VCO input, the search signal generator when receiving the first signal from the lock signal generator providing a varying voltage to the VCO input to sweep a frequency at the VCO output through the 30   range of frequencies which can be provided by the signal from the collision avoidance radar system, the search signal generator when receiving the second signal from the lock signal generator disabling its output; and

an integrator (640) including a switch 35   connected in parallel with a capacitor for coupling the output of the second multiplier through a summer to the input of the VCO, the switch being connected to the lock

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signal generator so that the switch is controlled to close when the lock signal generator provides the first signal and open when the lock signal generator provides the second signal;
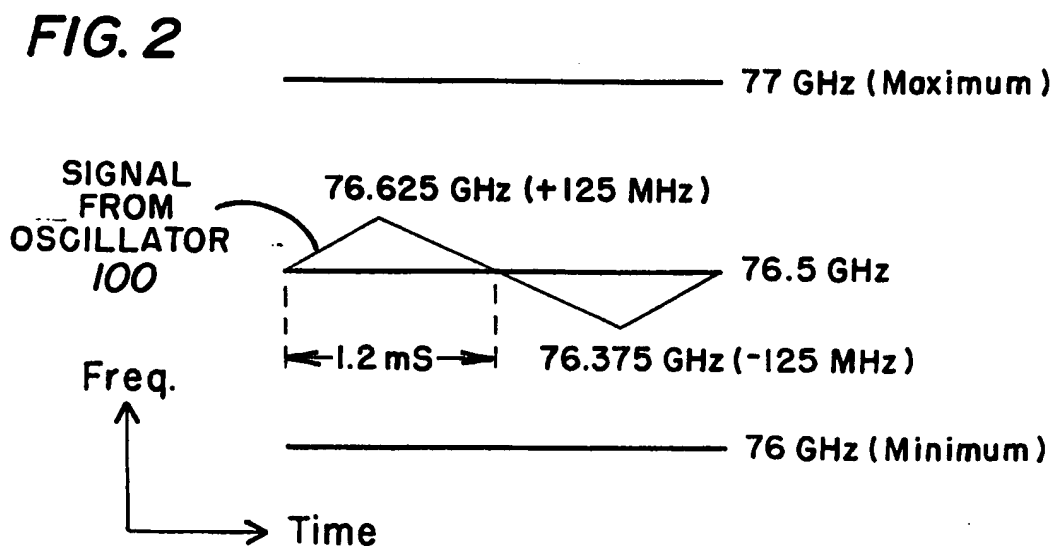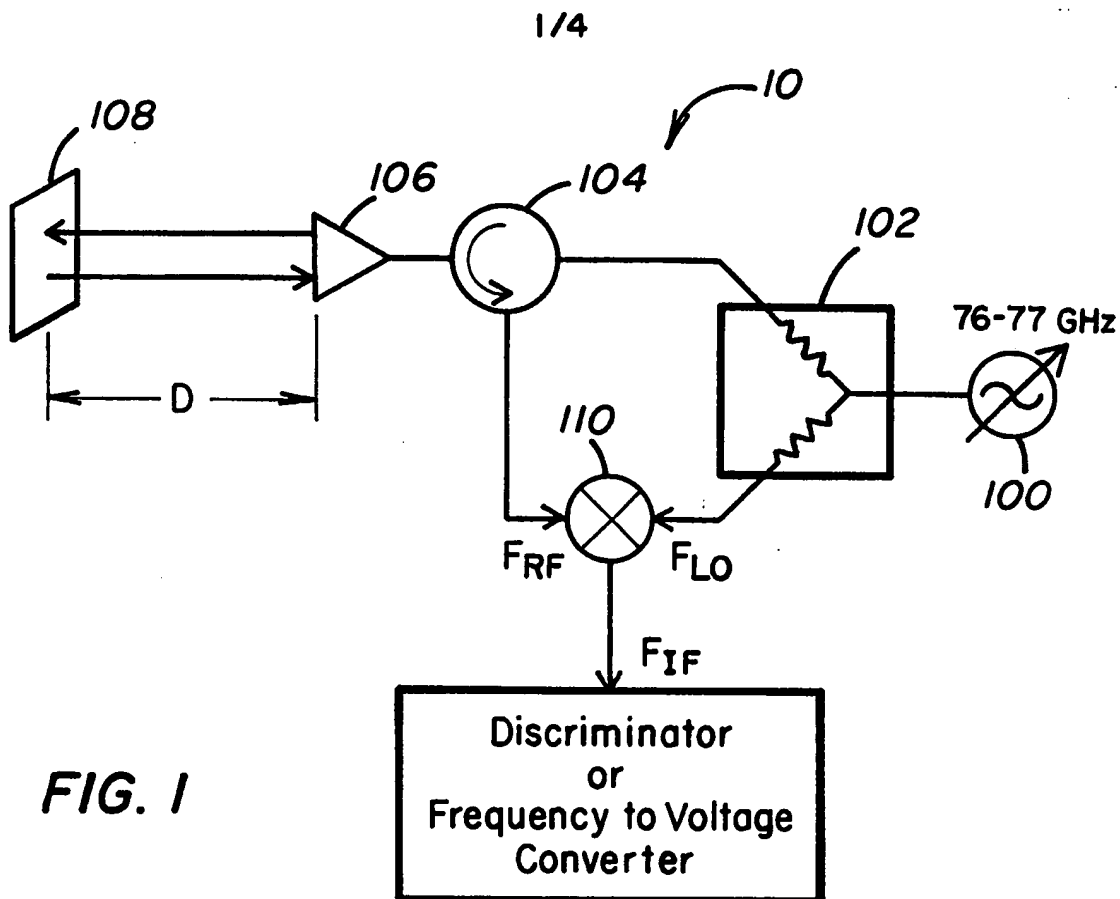
5   a differentiator (652) having an input connected to the output of the integrator of the phase detector and an output;
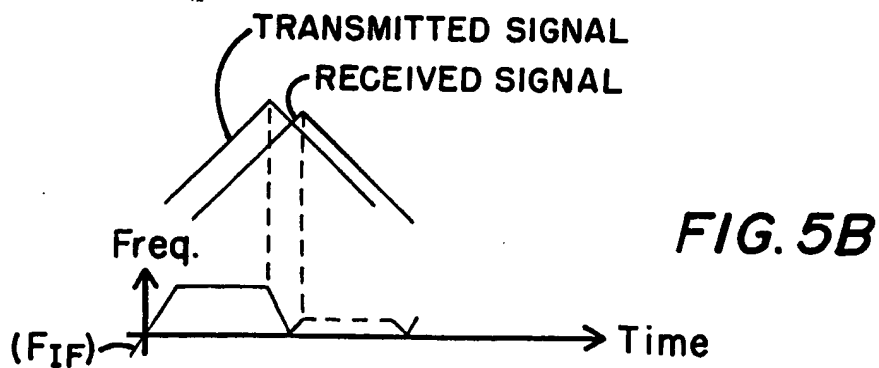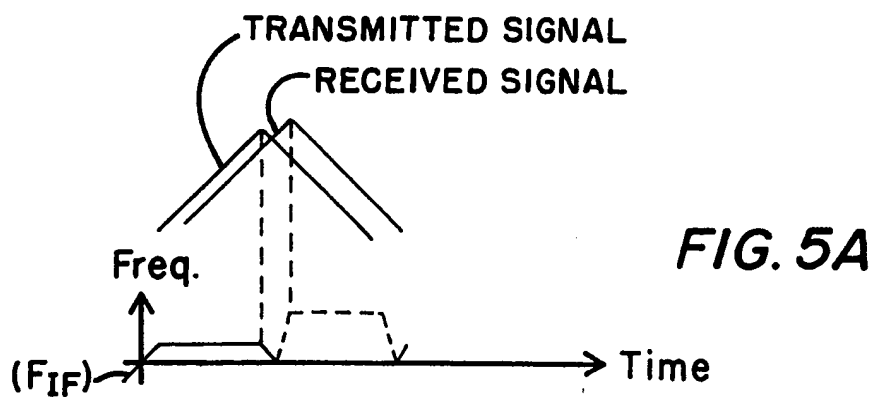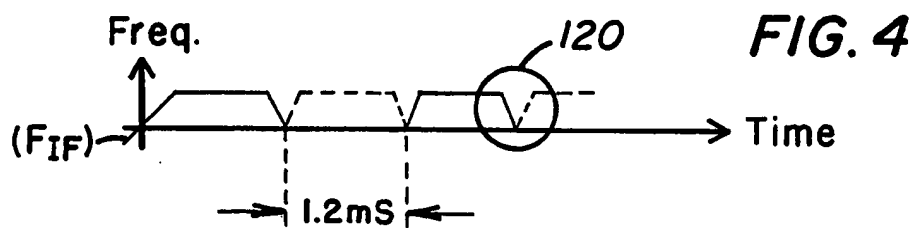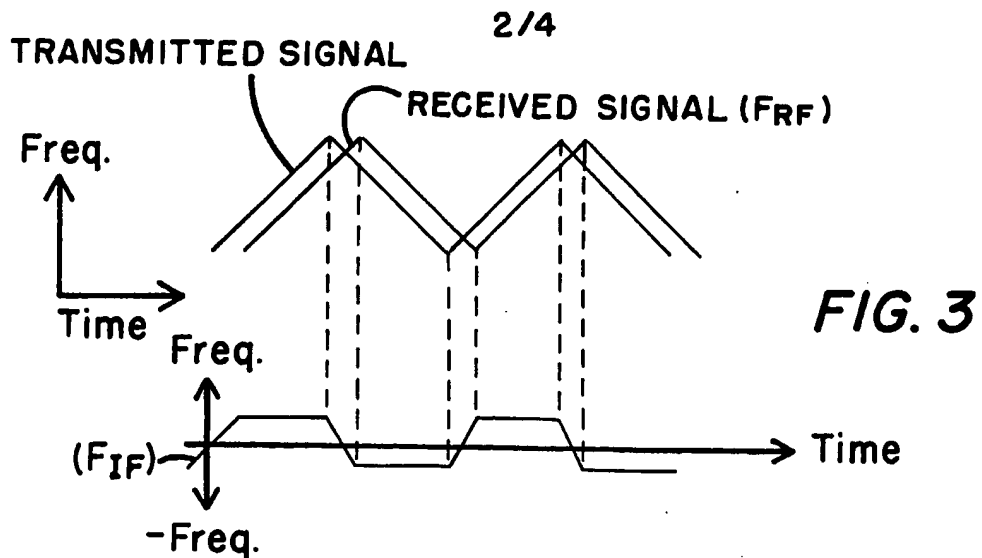
       a comparator (654) having a first input connected to the output of the differentiator, a second input

10   connected to a voltage reference and an output;

       an inverter (656) having an input connected to the output of the comparator and an output;

       first register (648) for storing a value, the first register having an output connected to the input of the

15   NCO and having an enable input connected to the output of the inverter; and

       a second register (650) for storing a value, the second register having an output connected to the input of the NCO and having an enable input connected to the
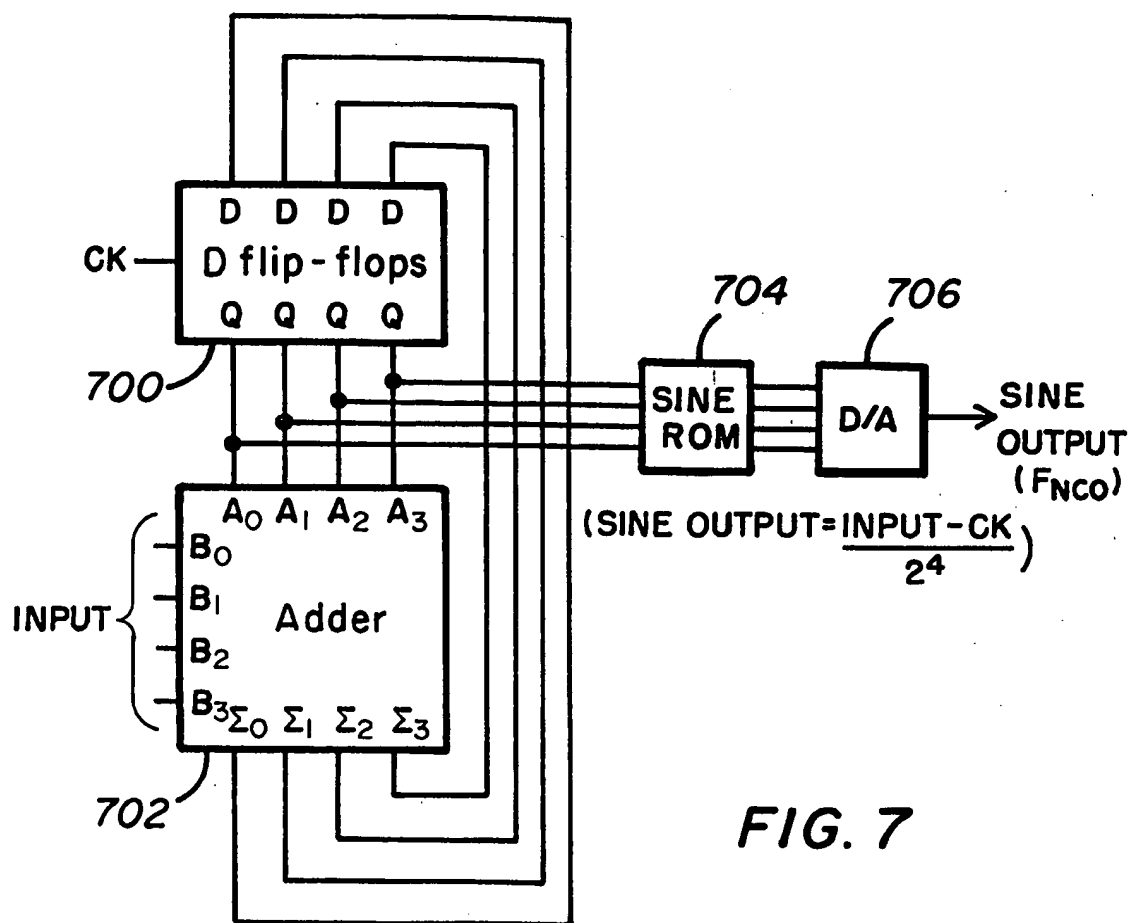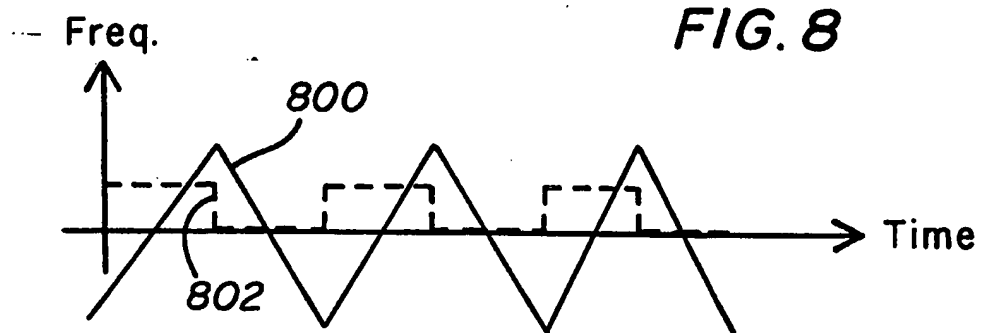
20   input of the inverter.

FIG. 1

FIG. 2

TRANSMITTED SIGNAL

RECEIVED SIGNAL (F_{RF})

Freq.

Time

Freq.

(F_{IF})

Time

-Freq.

FIG. 3

Freq.

120

(F_{IF})

Time

1.2mS

FIG. 4

TRANSMITTED SIGNAL

RECEIVED SIGNAL

Freq.

(F_{IF})

Time

FIG. 5A

TRANSMITTED SIGNAL

RECEIVED SIGNAL

Freq.

(F_{IF})

Time

FIG. 5B

FIG. 6

(SINE OUTPUT = $\dfrac{\text{INPUT} \cdot \text{CK}}{2^4}$)

FIG. 7
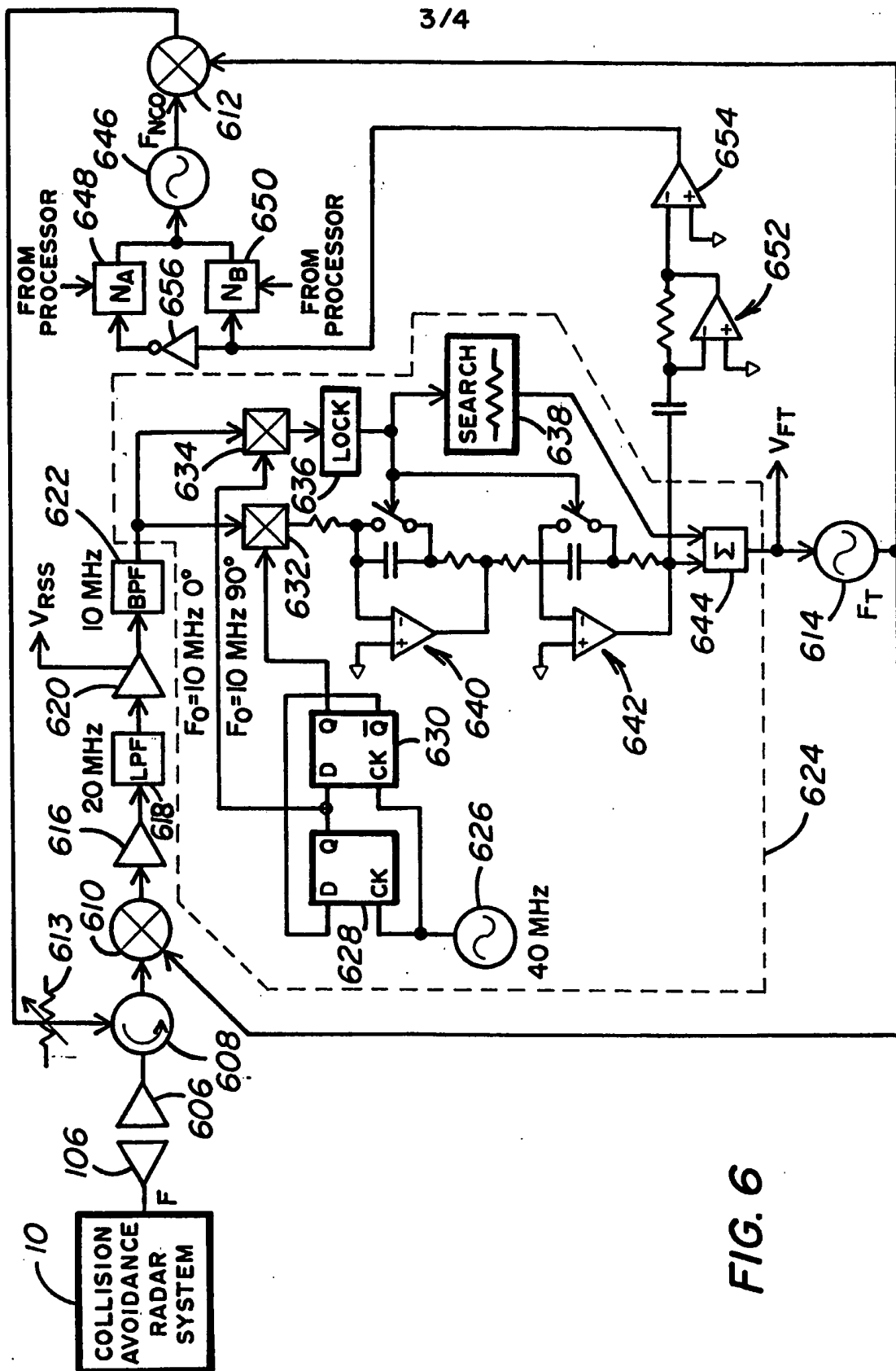
FIG. 8

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6   G01S7/40

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6   G01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 182 418 A (TRT TELECOM RADIO ELECTR ;PHILIPS NV (NL)) 28 May 1986 see column 6, line 1 - line 68; figures 1,4 see column 11, line 47 - column 12, line 59 ---	1,4
Y	US 4 435 712 A (KIPP RONALD W) 6 March 1984 see column 3, line 18 - line 47; figure 1 see abstract ---	1,4
A	PATENT ABSTRACTS OF JAPAN vol. 096, no. 008, 30 August 1996 & JP 08 102771 A (TOSHIBA CORP;TOSHIBA AVE CORP), 16 April 1996, see abstract ---	4,10

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| X | Further documents are listed in the continuation of box C. | | X | Patent family members are listed in annex. |

Date of the actual completion of the international search	Date of mailing of the international search report
25 March 1998	1 4. 04. 98

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Breusing, J

Form PCT/ISA/210 (second sheet) (July 1992).

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category°	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 0 359 911 A (MESSERSCHMITT BOELKOW BLOHM) 28 March 1990 see column 2, line 34 - column 3, line 9; figure 1 ---	1
A	EP 0 667 536 A (DAIMLER BENZ AEROSPACE AG) 16 August 1995 see column 2, line 34 - line 58; figure 1 -----	

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